

DIATOMS AS WATER QUALITY INDICATORS: Part II

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Abstract: Part I of this study was conducted during the 1967-74 period and was reported in PHYTOLOGICA, Vol 30, #5, 1975. At that time a comparison was made between the diatom flora of three clean feeder streams and the highly polluted Nashua River. Five diatom species collected in the highly polluted river were considered potentially useful as water quality indicators. The present study was conducted during the 1975-78 time period, this follows the construction of two multimillion dollar waste water treatment plants designed to "clean-up" the Nashua River at Fitchburg, Massachusetts. The treatment plants are now in operation and although not operating at 100% efficiency at this time, a noticeable improvement in the appearance of the Nashua River has taken place. The purpose of this study is to report changes in the diatom flora since the original study and continue the evaluation of diatoms as water quality indicators.

The Study Area: The Nashua River is a tributary of the Merrimack River located in central New England. The Nashua drains an area of 1170 km² in the North Worcester County area of central Massachusetts and 228 km² in the south central area of New Hampshire. The overall gradient of the river is shallow, dropping 158m over its 8km length. The bedrock of the study area is composed of granite (and related igneous rocks) and metamorphic rocks such as schist and gneiss. The surface geology is a complex of weathered bedrock and glacial deposits including sand and gravel deposits in the form of outwash, eskers and drumlins. More than 75% of the basin is covered with second-growth mixed coniferous-hardwood forest. The above factors contribute to an overall acidic nature of the water in this region. The specific study area is the north branch of the Nashua River which has five small feeder streams that arise in the foothills of the 600km Wachusett Range. These streams are rather clean and are not considered polluted and provide good trout fishing waters. As the feeder streams combine to form the Nashua River at Fitchburg, Massachusetts the water is utilized by a large number and wide variety of industries including paper mills, plastic and metal finishing factories. In 1976, two multimillion dollar waste water treatment plants were completed and put into operation, thus the domestic and industrial waste of the city of Fitchburg (pop. 40,000) is removed from the river. The study design allows for the comparison of diatoms collected from 3 clean feeder streams named Phillips Brook, Whittman River, and Old Mill Brook; with the diatoms collected from the Nashua

River at a site located south of the city of Fitchburg where Massachusetts Highway Route #2 crosses the river.

Methods: Routine chemical and physical examination of the water has been made over the four year period from 1975-78. A Hach Engineers Portable Water Testing Laboratory (Model Dr-E1) was used. The Millipore filter coliform technique was used for bacteria study. The five day, 20C B.O.D. technique was used for Biological Oxygen Demand data. The chemical and physical data vary with season, time of day and water levels. Due to some technical problems with the operation of the waste water treatment plants, the chemical load of the Nashua River is not constant and at time some domestic and industrial pollutants are introduced into the river for short periods of time.

Diatom collections were made at the three feeder stream sites and at the Nashua River site. Rock and plant scrapings were made along with diatometer samples. Diatometer slides were collected after being suspended in the water for a period of 7 days. Diatoms were "cleaned" by using the hydrogen-peroxide/potassium-dichromate method. The cleaned material was placed on #1 cover slips and mounted in Hyrax on microscope slides for study under oil immersion. The following species list is based upon 500-800 diatom counts per slide and are expected to represent at least 80% of the taxa present.

Table 1. Diatom Species Collected (1975-78) Numbers indicate % of total population. + indicates that the species was present but not counted in detail. - indicates not present in this study. * indicates organic pollution indicator taxa from other studies.

#1=Nashua River	#2=Old Mill	#3=Whittman R.	#4=Phillips Brk.			
1975-78 study		1	2	3	4	sites reported in 1967-74 study
Achnanthes affinis-affinis		1.0	1.7	0.9	+	1,2,3,4
A. clevei-cleveii *		-	0.3	0.4	+	not reported
A. clevei-rostrata		-	0.6	-	-	not reported
A. exigua-contucta		+	-	-	-	not reported
A. exigua-heterovalvata		+	0.4	+	+	not reported
A. hungarica-hungarica		-	0.5	0.5	0.8	1
A. lanceolata-lanceolata		-	0.7	+	3.9	2
A. lanceolata-dubia		-	0.5	0.3	-	not reported
A. lanceolata-lanceolatoides		+	0.6	+	0.4	3,4
A. linearis-pusilla		-	-	-	0.3	4
A. minutissima-minutissima		+	0.3	+	1.3	not reported
Amphipleura pellucida-pellucida		-	+	0.3	-	not reported
Amphora ovalis-affinis		-	0.2	-	-	2
Asterionella formosa-formosa		-	-	0.4	-	1,2,3,4
Caloneis amphisbaema-amphisbaema		-	+	+	-	not reported

#1=Nashua River #2=Old Mill #3=Whittman R. #4=Phillips Brook					sites reported in 1967-74 study
	1	2	3	4	
<i>Caloneis bacillum bacillum</i>	0.6	2.8	1.9	0.6	not reported
<i>Cocconeis placentula placentula</i> +	0.9	-	0.6	-	2
<i>C. placentula euglypta</i>	2.0	4.3	6.8	9.1	2,3,4
<i>C. placentula lineata</i>	16.8	7.5	4.2	30.7	4
<i>C. pediculus pediculus</i>	-	0.6	-	-	not reported
<i>Cyclotella glomerata glomerata</i>	-	0.4	0.4	-	2
<i>C. meneghiniana meneghiniana</i>	0.5	5.1	1.3	1.0	1,2,4
<i>C. stelligara stelligara</i> *	0.8	6.3	0.8	1.8	2,3,4
<i>Cymbella aspera aspera</i>	-	+	1.3	+	2,3,4
<i>C. cuspidata cuspidata</i>	-	-	-	+	not reported
<i>C. minuta minuta</i> *	-	0.9	0.8	0.5	not reported
<i>C. microcephala microcephala</i>	-	0.6	-	-	not reported
<i>C. naviculiformis naviculiformis</i> -	-	-	0.4	-	not reported
<i>C. triangulum triangulum</i>	-	-	-	0.4	not reported
<i>C. tumida tumida</i>	-	-	+	+	not reported
<i>C. turgida turgida</i>	+	0.8	0.4	1.0	not reported
<i>Diatoma anceps anceps</i>	+	-	1.0	-	4
<i>D. vulgare vulgare</i> *	-	-	1.0	-	not reported
<i>Eunotia arcus arcus</i>	-	+	1.3	-	1,2
<i>E. curvata curvata</i> *	-	0.7	2.6	+	1,2,3,4
<i>E. diodon diodon</i>	-	0.5	+	-	4
<i>E. fallax fallax</i>	-	-	+	-	3,4
<i>E. monodon monodon</i>	-	1.4	2.9	0.8	2,3,4
<i>E. pectinalis pectinalis</i> *	+	0.7	1.2	-	2
<i>E. pectinalis minor</i>	+	0.4	0.6	+	1,2,3,4
<i>E. serra serra</i>	-	-	+	-	not reported
<i>E. tridentula perminuta</i>	-	-	-	+	2
<i>Fragilaria brevistriata</i> *	-	4.2	-	-	not reported
<i>F. construens construens</i> *	+	-	2.4	+	2,4
<i>F. crotonensis crotonensis</i> *	+	0.7	3.0	-	1,3,4
<i>F. pinnata pinnata</i> *	-	1.1	-	+	3,4
<i>F. vaucheriae vaucheriae</i> *	-	9.6	0.6	-	1,2,4
<i>F. virescens virescens</i>	+	-	0.4	-	2,3,4
<i>F. virescens capitata</i>	-	0.9	0.4	-	not reported
<i>Frustulia rhomboides</i>	-	-	0.8	-	4
<i>F. rhomboides saxonica</i>	-	0.4	+	-	2,3,4
<i>F. rhomboides viridula</i>	-	0.6	+	0.5	1,2
<i>F. vulgaris capitata</i>	-	3.1	-	-	not reported
<i>Gomphonema angustatum major</i>	-	3.1	-	-	2,3
<i>G. angustatum sarcophagus</i>	-	1.5	0.4	-	2
<i>G. constrictum capetata</i> *	-	0.4	-	+	4
<i>G. cumrhis cumrhis</i>	-	0.4	-	-	not reported
<i>G. parvulum parvulum</i>	1.5	6.3	2.4	2.4	1,2,3,4
<i>G. parvulum micropus</i>	-	0.9	-	-	not reported
<i>G. tenellum tenellum</i>	-	0.4	-	-	not reported
<i>G. sphaerophorum sphaerophorum</i>	-	0.4	-	-	not reported
<i>G. truncatum turgiatum</i>	-	-	0.4	-	not reported
<i>Melosira granulata granulata</i>	-	2.6	1.6	2.9	1,2,3,4

#1=Nashua River	#2=Old Mill	#3=Whittman R.	#4=Phillips Brook	sites reported in 1967-74 study	
	1	2	3	4	
Melosira distans alpigena	-	-	1.0	2.4	
M. distans distans	0.4	2.6	6.2	3.8	not reported
M. granulata angustissima	-	-	1.4	2.1	1,2,3,4
M. varians varians	-	1.8	0.6	8.8	4
Meridion circulare circulare	+	+	1.9	0.4	1,2,3,4
Navicula amphibola amphibola	+	-	-	-	not reported
N. anglica anglica	-	+	-	-	not reported
N. cuspidata cuspidata *	0.6	4.7	2.1	0.6	1,2
N. dicephala rostrata	-	+	-	-	not reported
N. lanceolata lanceolata*	1.0	1.0	1.4	+	1,2,3,4
N. minima minima*	-	-	0.4	-	1,2,3,4
N. mutica mutica	-	-	+	-	not reported
N. placenta placenta	-	-	-	+	2
N. pupula pupula *	-	0.6	+	-	1,2,4
N. pupula elliptica	-	-	0.4	-	not reported
N. pupula rectangularis	+	-	+	-	1,2,4
N. rhynchocephala *	0.4	2.4	5.9	1.6	1,2,3,4
N. viridula angunesis	+	-	-	-	not reported
N. viridula linearis	-	0.4	+	-	not reported
Neidium affine affine	-	0.4	+	-	4
N. temperie temperie	-	+	-	-	not reported
Nitzschia amphibia amphibia*	45.0	-	-	-	1
N. capitellata capitellata	-	-	1.3	+	not reported
N. commutata commutata	1.6	-	-	-	not reported
N. communis communis*	-	-	+	+	not reported
N. dissipata dissipata*	0.8	-	0.4	0.6	1,2,4
N. filiformis filiformis	+	-	1.2	-	1,2,3,4
N. linearis linearis *	0.4	-	-	-	not reported
N. palea palea*	1.6	-	2.6	0.5	1,2,3,4
N. sigma sigma	0.6	+	+	+	not reported
N. thermalis minor	25.6	-	-	-	2
N. thermalis thermalis	-	-	0.4	-	not reported
Opehora martyi martyi*	-	0.5	-	-	not reported
Pinularia acrosphaeria	-	-	+	+	not reported
P. brebissoni brebissoni	0.9	+	0.4	-	3,4
P. viridis viridis	-	0.6	+	-	2,3
Stauroneis anceps linearis	-	-	+	-	not reported
S. phoenicenteron phoenicenteron	-	+	+	-	1,3,4
S. phoenicenteron gracilis	-	-	+	-	not reported
Surirella angustata angustata	-	0.4	0.4	1.2	1,2
S. linearis constricta	-	-	0.8	-	4
S. ovata ovata	+	1.4	1.2	-	1
S. turgida turgida	-	-	+	+	not reported
Synedra rumpens rumpens*	-	0.6	6.7	6.8	1,2,3
S. rumpens fragilarioides	-	-	1.0	+	not reported
S. ulna ulna	1.0	1.3	3.2	1.4	2,4
Tabellaria fenestrata fenestrata	-	1.2	2.0	1.6	3,4
T. flocculosa flocculosa	-	1.5	4.4	1.0	1,2,4

Results: 111 diatom species were identified from the four collecting sites and are listed in table 1. 46 species identified were new to the 1975-78 study. As expected, some species (31) were collected in both the feeder streams and the Nashua River. 72 species were identified from the three feeder streams and were not present in the Nashua River. Only 7 diatom species were identified only from the Nashua River, they are:

Acanthes exigua-contucta, Navicula amphibola-amphibola, Navicula viridula-anguensis, Nitzschia commutata-commutata, Nitzschia linearis-linearis, Nitzschia amphibia-amphibia, and Nitzschia thermalis-minor.

The five diatom species identified from the highly polluted Nashua River in the 1967-74 study were: Acanthes hungarica, Nitzschia amphibia, Surirella ovalis, Surirella ovata pinnata, and Synedra rumpens.

When an evaluation of these species as water quality indicators is done in light of the 1975-78 study, Acanthes hungarica and Synedra rumpens are considered not useful as pollution indicators because they are found in all three clean feeder streams in the 1975-78 study. Since Surirella ovalis and Surirella ovata pinata were not found in the 1975-78 study, they are of possible interest as they were tolerant of the serious pollution conditions during the 1967-74 study but now are not present under improved conditons. Nitzschia amphibia present in the Nashua in both the 1967-74 and 1975-78 collections and not reported from feeder streams is true to form and is of interest as a pollution indicator. 15 species are common to all three feeder streams and are of possible interest as clean water indicators.

Diatoms known to be organic pollution indicators have been reported by Lowe (1974). Of the species listed by Lowe, 30 are included in this study and are marked with an asterisk in table 1. Diversity, as shown in table 2, has increased for three of the four streams studied. The percent of the population made up of pollution indicator taxa has in every instance gone down. During the 1967-74 study, more than 50% of the observed diatoms in the Nashua River were represented by two diatom taxa. In the second study, 1975-78, three taxa make up 50% of the diatom population in the Nashua River.

Table 2: Diatom Population Diversity and Structure

	Nashua	Old Mill	Whittman	Phillips
1967-74 study				
Total taxa present (diversity)	31	56	45	61
% pop. as indicator species	61%	44%	33%	22%
1975-78 study				
Total taxa present (diversity)	38	71	82	56
% pop. as indicator species	49%	39%	32%	21%

Conclusions: The shift in diatom species found in the Nashua River supports the idea that diatoms are sensitive to water quality, however, a wide range of physical and chemical parameters are involved and their interaction makes a clear focus on quality indicator species difficult. Certainly one must be cautious of universal "master lists" of pollution indicators such as the one given by Palmer (1969). Specific indicator lists should be developed for individual aquatic systems.

Single species of diatoms by themselves do not seem to be useful as quality indicators, however when included in groups or "assemblages" and considered in relation to the total make-up of the diatom flora, diatoms become useful as water quality indicators. The more diverse the diatom population the more stable and natural the stream may be. If two or three species of diatoms make up more than 10% of the total diatom population, there are indications that the waterway is under stress, at least part of the time.

The chemical/physical data of this report (table 3) when compared to the 1967-74 study shows considerable improvement in the nitrate-phosphate complex and a lowered coliform count. Other factors are stable, thus it can be interpreted to mean that the river quality is improving without undo stress being placed on the system during the change.

Table 3: Physical and Chemical Data (1975-78)

	Nashua R.	Old Mill	Whittman	Phillips
Dissolved Oxygen	4-12 ppm	7-13 ppm	6-13 ppm	7-14 ppm
Water Temperature	2-25C	0-20C	0-20C	0-21C
pH	6.5	6.5	6.5	6.5
Total Hardness	45 ppm	50 ppm	45 ppm	50 ppm
Turbidity (JTU)	5-110	0	10	0
Phosphate	1.4 ppm	trace	trace	trace
Nitrate	4 ppm	trace	trace	trace
Ammonia	1.5 ppm	0	0	0
B.O.D.	3-9 ppm	2 ppm	3 ppm	2 ppm
Coliform/50ml	35-310	20	18	28

The diatom data of this study reveals some interesting long term results. The increase in total diatom diversity from 99 to 111 should be considered a positive sign. The Nashua River shows improvement with diversity up from 31 to 38 taxa. At the same time the per cent of the population made up of organic pollution taxa has dropped from 61% to 49%. This must be acknowledged as a significant shift of water quality in the right direction. The trend of greater diversity and lower per cent of pollution indicator taxa holds true for the Old Mill Stream and the Whittman River. It is interesting to note that the apparently clean trout stream, Phillips Brook, has a diversity drop and thus this

body of water warrants careful monitoring at this time. Diatoms are useful not only for indication of present conditions but can indicate long term trends of improvement or degradation as it develops. This study points up the much improved but as yet incomplete clean-up of the Nashua River in this study area.

References:

- Palmer, C.M. A Composite Rating of Algae Tolerating Organic Pollution Journal of Phycology #5 1969
- Lowe, Rex L. Environmental Requirements and Pollution Tolerance of Freshwater Diatoms U.S. Govt. Printing Office, Washington, D.C. 1974 334 p.
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A. I. GALUSHKO, "FLORA OF THE NORTHERN CAUCASUS", A REVIEW

Otto & Isa Degener

After attending the meetings of the XII International Botanical Congress in Leningrad in 1975 as mentioned *before, we joined the Caucasus Tour conducted by Prof. Galushko. We were amazed at Dr. Galushko's intimate knowledge of the ferns, "fern alles," gymnosperms and phanerogams about him, and a bit saddened that this wealth of personal knowledge was not generally available. We are now delighted to report that we just received a copy of the 318-page "Flora of the Northern Caucasus" from our friend.

Though the volume, in boards, is published in Russian in the Cyrillic alphabet, names of Families and lower categories appear in the Roman. Thus we "outsiders" can gain an intriguing bird's eye views of what genera, so many common to temperate North America, exist there. The almost 3,900 species, according to our perusal of the index, are scattered among about 360 genera in 54 families.

Actually a field guide with emphasis on geographic distribution, this vade mecum is enhanced with 76 plates and figures. A few trivial misspellings occur, one being that of "Pulsatilla" under one of the cuts.

Unable to translate into English the information given where copies can be purchased, we suggest writing for them to the author at his home: Fevral'skaya Street 273, T. Pyatigorsk, 357528, U.S. Russia.

*Phytologia 17(4):409-411. 1977.